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(54) **METERING HYDRAULIC CONTROL SYSTEM FOR MINING MACHINE**

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F15B 13/06	(2006.01)

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(58) **Field of Classification Search**
CPC F15B 11/006; F15B 13/06; F15B 13/07
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,250,794 A	2/1981	Haak et al.		
5,794,511 A *	8/1998	Sorbel	E02F 9/2267	91/536
6,431,050 B1	8/2002	Hausman et al.		
6,467,264 B1 *	10/2002	Stephenson	F15B 11/006	60/368
6,748,738 B2 *	6/2004	Smith	E02F 9/2217	60/414
7,905,088 B2 *	3/2011	Stephenson	F15B 11/024	60/414

(Continued)

FOREIGN PATENT DOCUMENTS

JP	S60203742 A	10/1985
RU	238734 C1	4/2010

(Continued)

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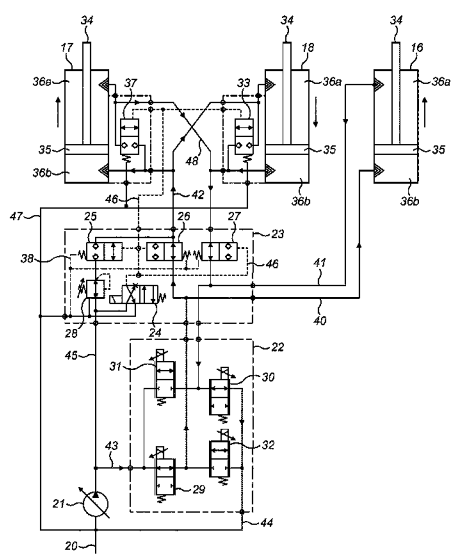
(57) **ABSTRACT**

A hydraulic system arranged to control at least two hydraulic actuators via a metering control valve assembly. The hydraulic system is advantageous to control a pivoting arm of an undercutting mining machine according to at least two modes of operation including an idling mode and a cutting mode. In particular, the hydraulic actuators may be controlled by quantitative variation of fluid flow speed and pressure.

17 Claims, 6 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

9,068,578	B2 *	6/2015	Opdenbosch	E02F 9/2289
9,151,081	B2 *	10/2015	Thomson	E05B 65/5284
10,358,797	B2 *	7/2019	White	E02F 9/2267
10,526,767	B2 *	1/2020	Hijikata	E02F 9/2217
2002/0148223	A1	10/2002	Reiners et al.	
2003/0106423	A1	6/2003	Hajek et al.	
2012/0152629	A1	6/2012	Mather et al.	
2013/0081383	A1	4/2013	Knussman	
2014/0325972	A1 *	11/2014	Ma	E02F 9/2292 60/327

FOREIGN PATENT DOCUMENTS

SU	1652468	A1	5/1991
WO	2016055087	A1	4/2016

* cited by examiner

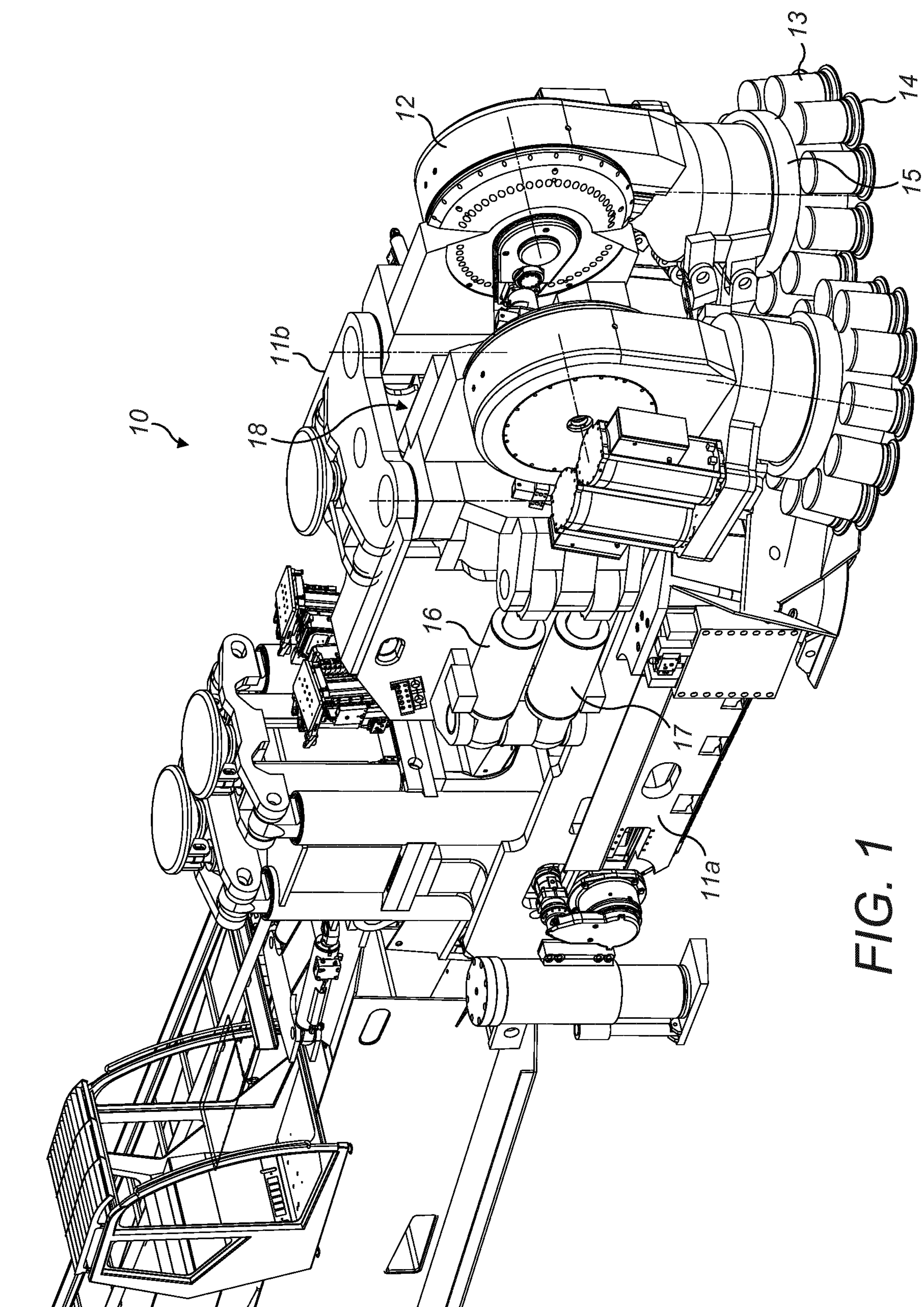


FIG. 1

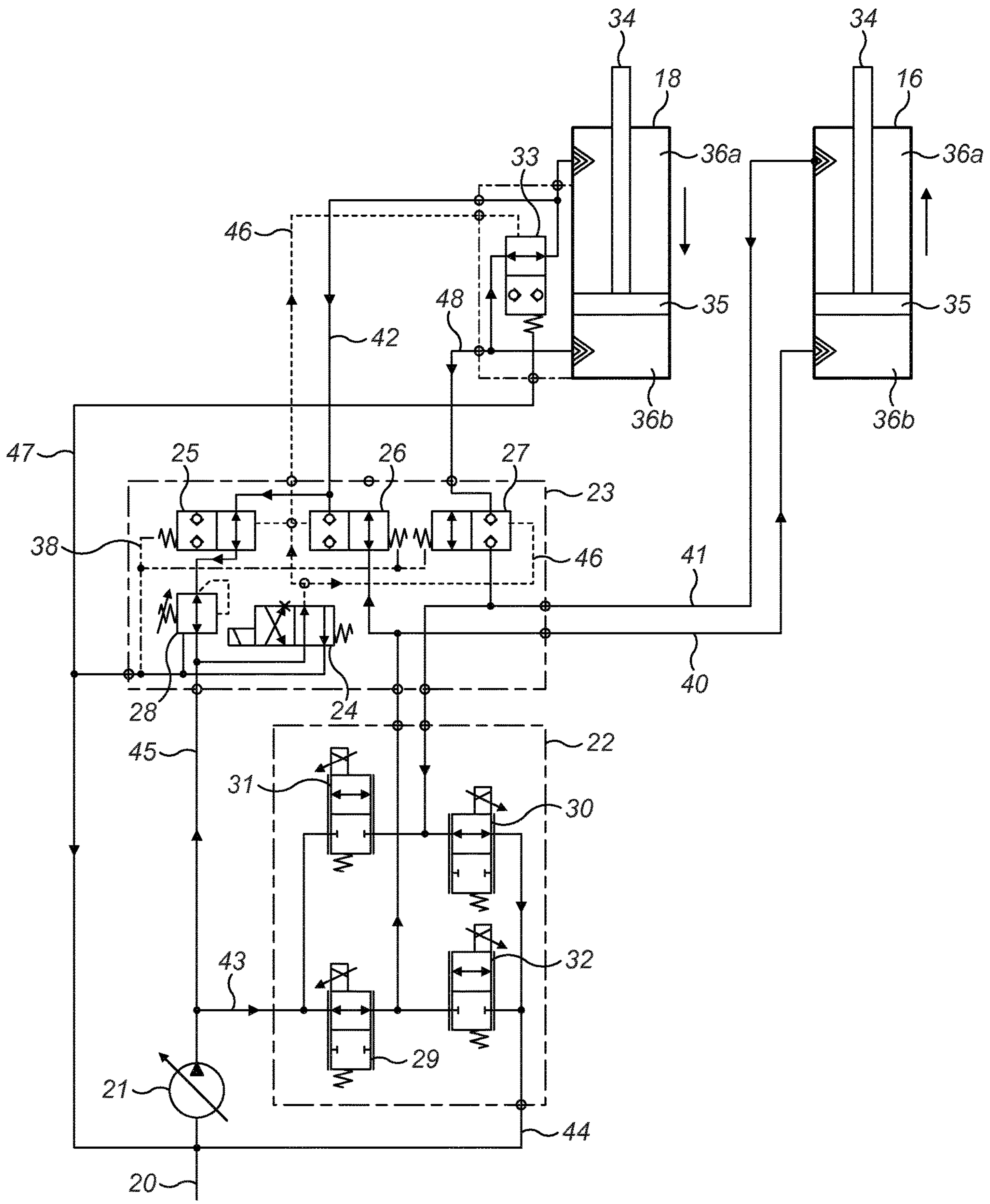

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FIG. 2

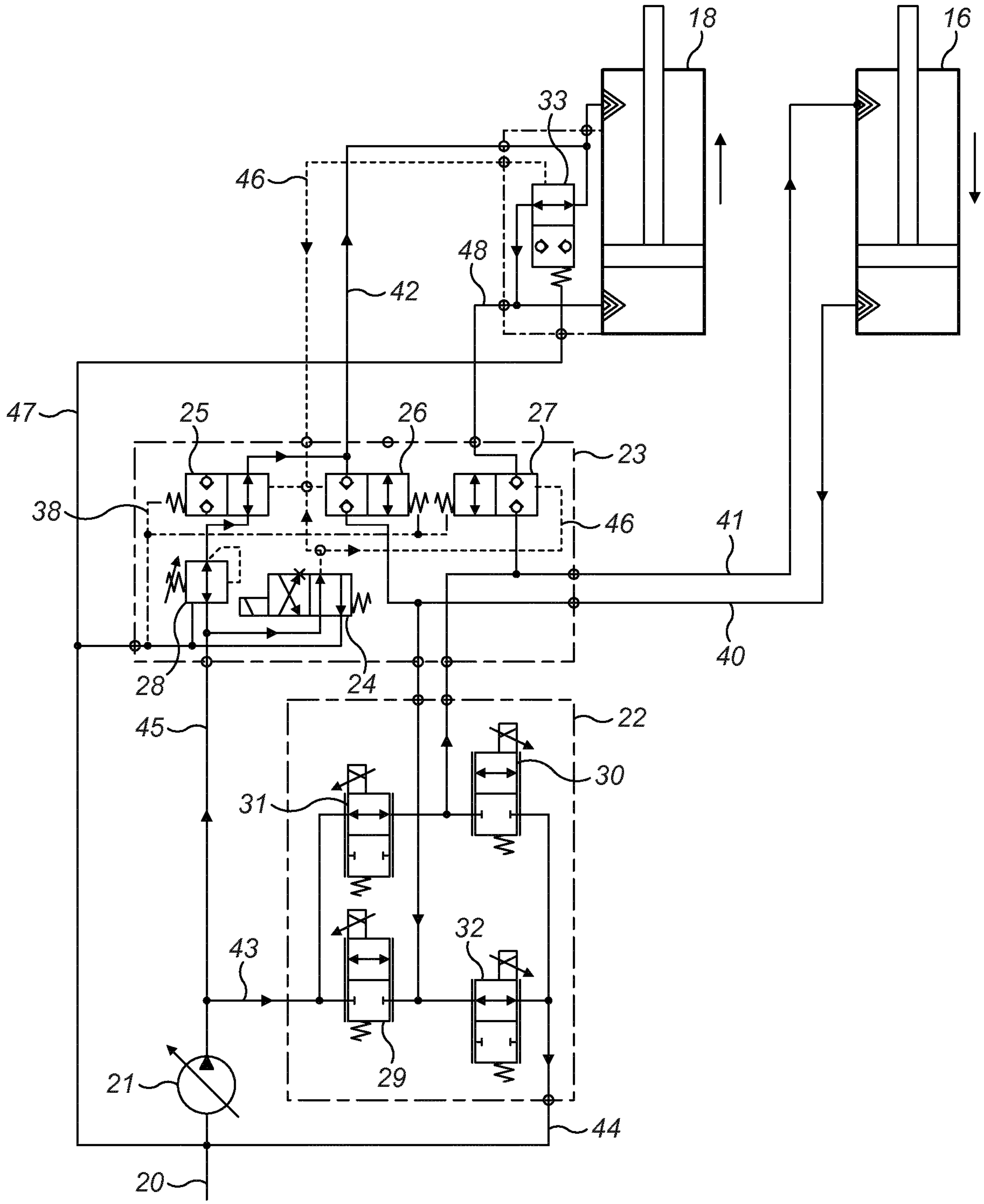
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FIG. 3

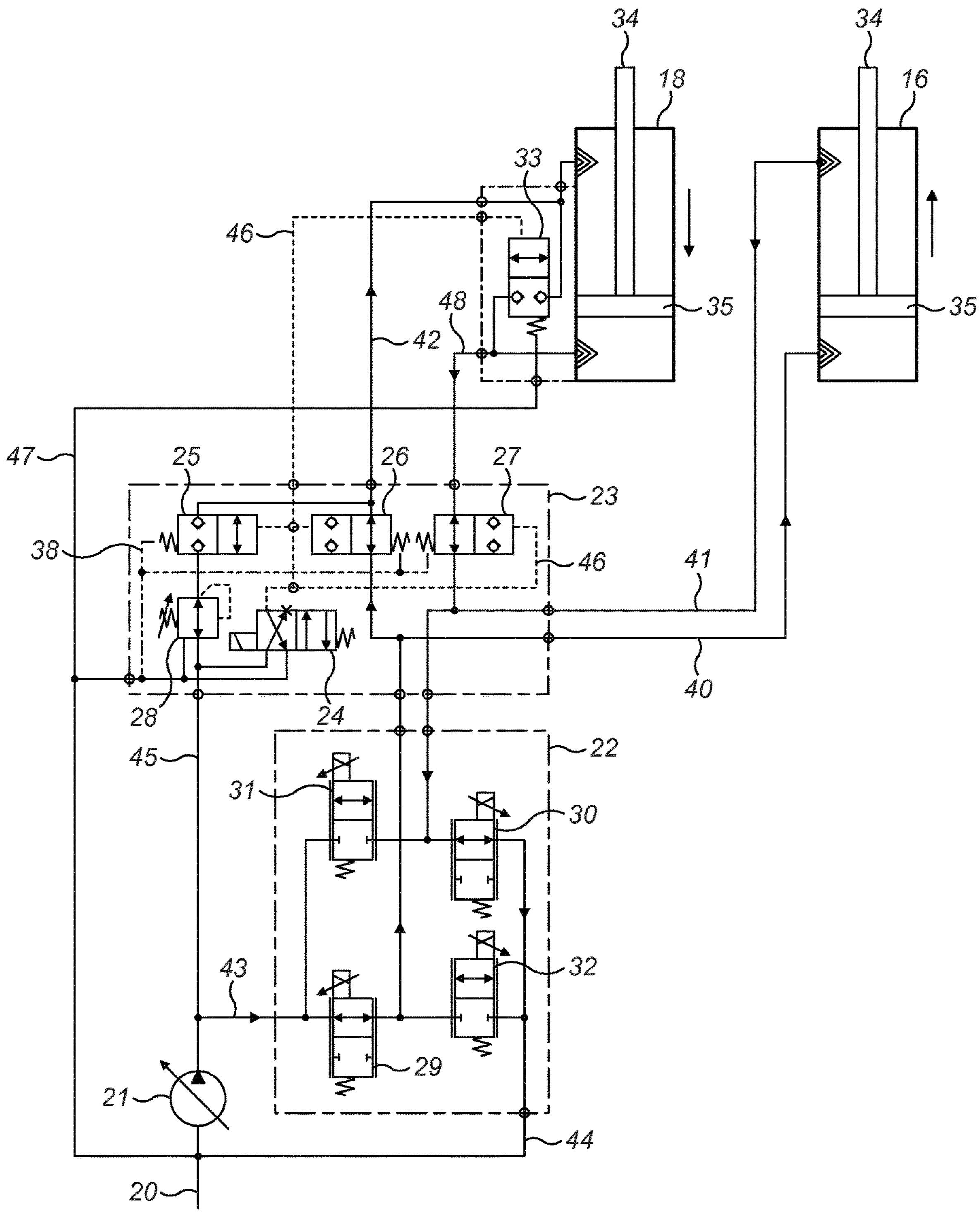
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FIG. 4

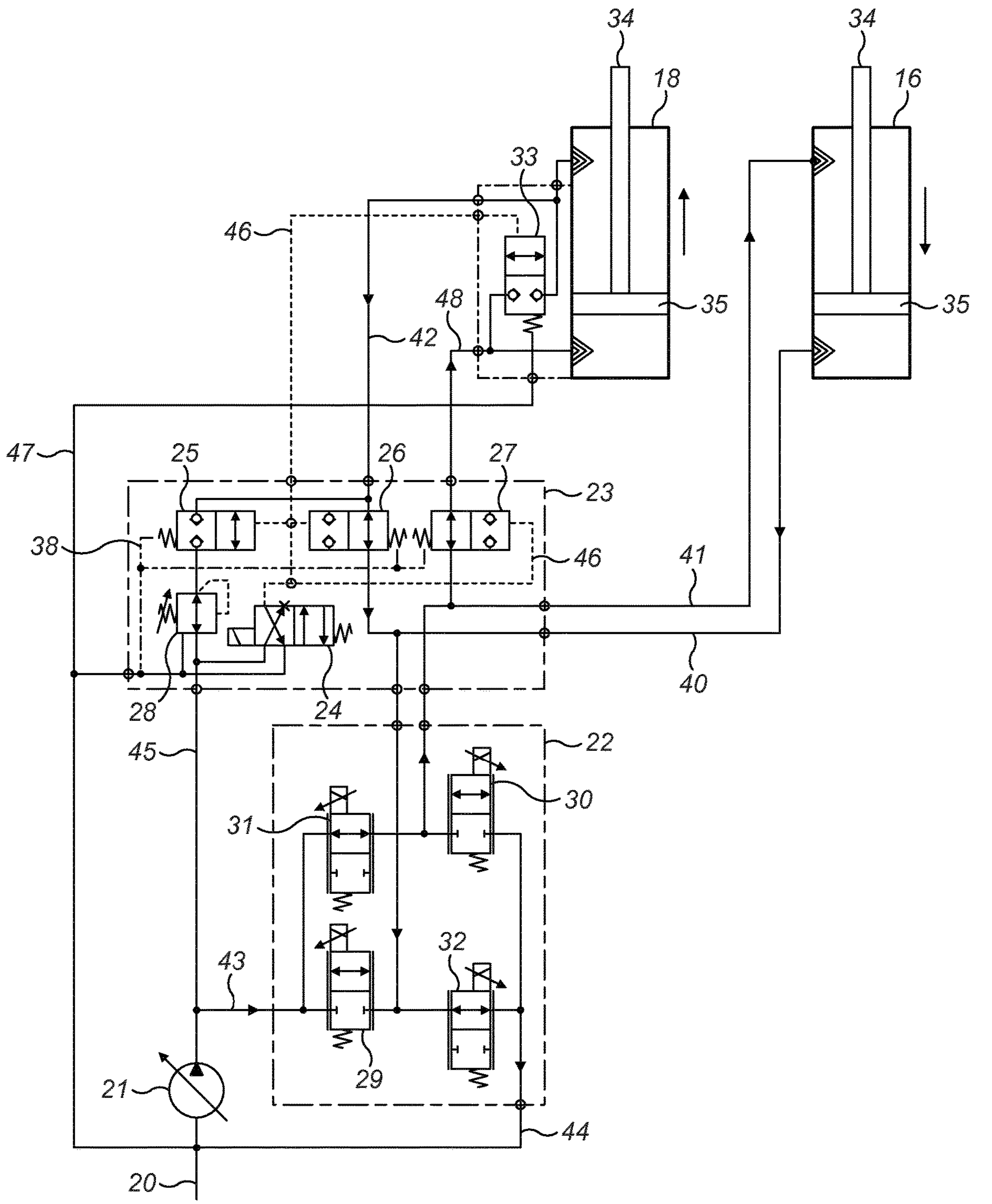
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FIG. 5

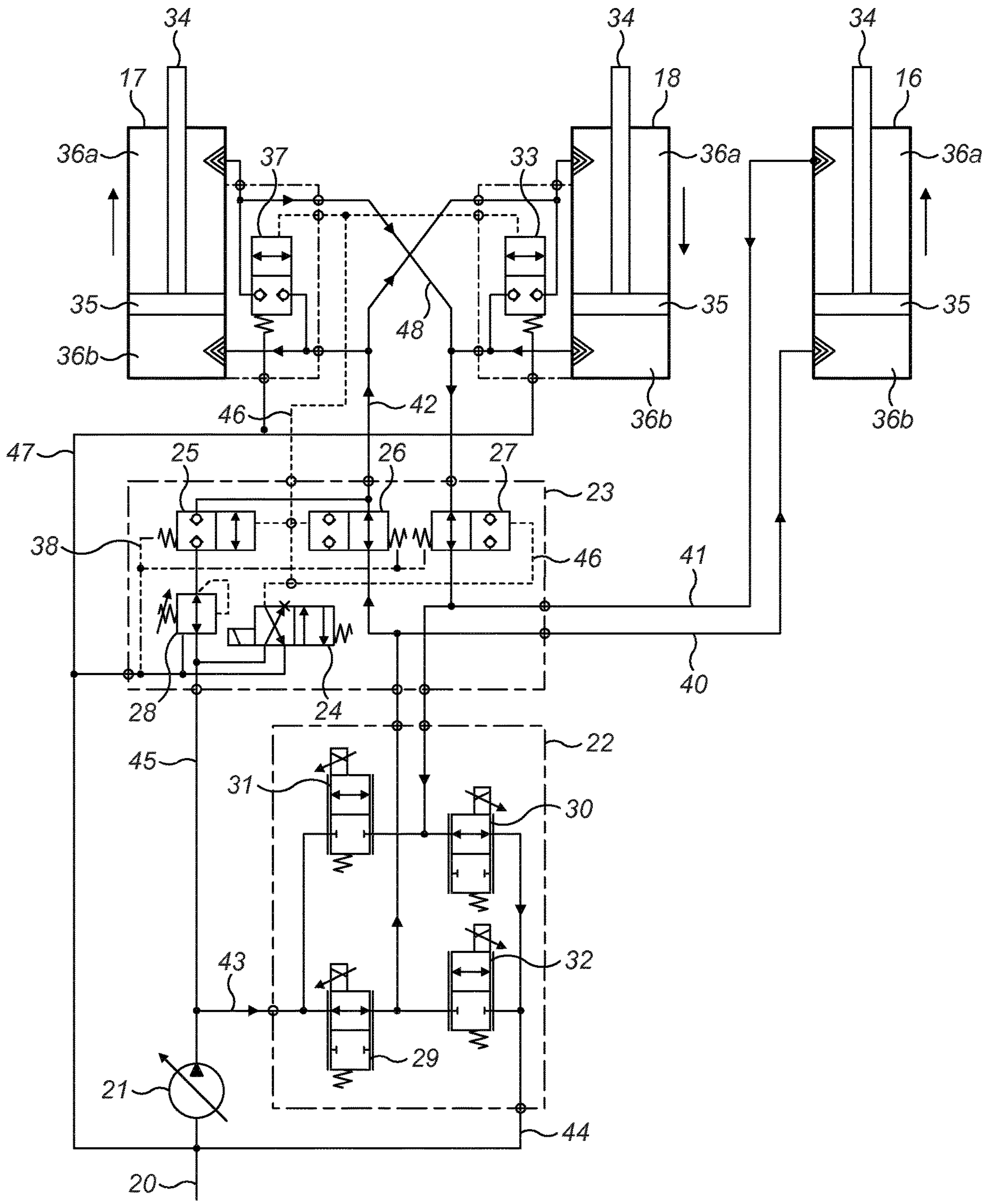
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FIG. 6

METERING HYDRAULIC CONTROL SYSTEM FOR MINING MACHINE

RELATED APPLICATION DATA

This application is a § 371 National Stage Application of PCT International Application No. PCT/EP2017/054341 filed Feb. 24, 2017.

FIELD OF INVENTION

A hydraulic system to provide actuation of a mechanical member, and in particular although not exclusively, to a hydraulic system having an actuator with independent metering control.

BACKGROUND ART

Independent metering valve (IMV) assemblies have been used for hydraulic control of actuators of heavy machinery that act on excavation buckets, loader front ends and the like. Typically, an IMV assembly receives pressurised hydraulic fluid from a pump and is coupled in fluid communication with a hydraulic load actuator such as a hydraulic cylinder that is mechanically linked to a mechanical actuator, i.e. loader bucket, mechanical arm etc. Conventionally, an IMV assembly includes four independently controllable valves in which a first pair is coupled with a first chamber (head end) of the cylinder and a second pair is coupled with a second chamber (rod end) such that selective hydraulic fluid flow between the respective pairs of valves provides either extension or retraction of the cylinder rod. Typically, the valves of the IMV assembly are electrically controlled independently and are configured to receive input signals from one or more sensors provided at the hydraulic circuit.

US 2013/0081383 discloses a hydraulic system in which a variable displacement pump is connected in a closed-loop manner to first and second linear actuators that operate to manipulate a pivoting boom of an excavator machine.

US 2003/0106423 discloses a fluid control system operable in either an independent function mode or a regenerative function mode.

US 2002/0148223 discloses a hydraulic system having a IMV assembly coupled to a first and second hydraulic load such as a cylinder or fluid motor driving a fan or the like.

However, conventional arrangements offer limited control of fluid flow speed, pressure and fluid flow direction through the circuit that in turn limits the range of functionality of the hydraulic and according the mechanical actuator. Accordingly, what is required is a hydraulic system that solves these problems.

SUMMARY OF THE INVENTION

It is one objective of the present invention to provide a hydraulic system capable of being fluidly connected to an actuator so as to provide a wide range of dynamic (adjustable) properties including in particular load force, speed of movement, accurate static and moving positional control in response to an external static and/or dynamic load forces. It is a further specific objective to provide a hydraulic system suitable for controlling a mechanically actuating member such as a boom, arm, linkage or other member associated with heavy machinery such as an excavator, mining machine or other bulk processing apparatus.

It is a specific objective to provide a hydraulic system for a cutting mining machine and in particular an undercutting mining machine capable of controlling actuation of one or more pivoting support arms of the machine that mount one or a plurality of cutting heads.

According to one aspect, a hydraulic system is provided having an independent metering valve (IMV) assembly in which electrically controlled meter-in and meter-out valves are configured to control a mechanical actuator (such as a cutter arm) to provide accurate movement and static positioning of the mechanical actuator both when the actuator is not externally loaded (other than by gravity) and in response to an external static and/or dynamic load forces. The present hydraulic system is specifically adapted for variation of speed of actuation and the force with which actuation is provided. For example, and in one mode of operation, hydraulic actuating cylinders, controlled by the present hydraulic system, may be maintained in a relatively 'stiff' configuration so as to be capable of withstanding significant loading forces, e.g., when the cutter arm is in a cutting mode, whilst maintaining position or whilst being actuated to provide pivoting of the cutter arm against the rock strata e.g., movement laterally inward and outward relative to a main body of the bulk processing machine. In a further mode of operation, the hydraulic actuating cylinders, may be controlled to provide fast movement of the cutter arm when not loaded e.g., when the cutting arm is in an idling (not cutting) mode.

The present hydraulic system is advantageous to provide independent metering of movable mechanical actuators such as pivoting support arms of cutting or other mining machines and other bulk processing apparatus. In particular, the subject invention provides control of one or a plurality of hydraulic load actuators (e.g. hydraulic cylinders) according to different operational modes such as a 'cutting' mode and an 'idling' mode. In the cutting mode the system is configured to control the hydraulic actuator to achieve a slow speed or movement with high loading force resistance (i.e., enhanced relative 'stiffness' of the actuator) and in the cutting mode to achieve a fast speed or movement with low loading force resistance (i.e., reduced relative 'stiffness' of the actuator) via the same independent IMV assembly. Accordingly, the subject invention is optimised for maximising efficiency of a mining machine so as to be capable of obtaining a desired fluid flow speed and pressure that may be proportionally adjusted so as to provide operation according to the cutting and idling modes in which at least one mechanical actuator is displaceable with a wide range of movement speeds and against a wide range of external forces (movement-resistive forces).

According to a first aspect of the present invention there is provided a hydraulic system to control at least two hydraulic actuators, the system comprising: a pump; a first and a second hydraulic actuator; a metering control valve assembly having a plurality of electrohydraulic valves, an inlet fluidly connected to the pump and an outlet fluidly connected to a drain or reservoir, the metering control valve assembly fluidly connected to the first hydraulic actuator; a transmission valve assembly having an electronically controllable valve fluidly connected to provide pilot control of a first and a second logic valve, the first and second logic valves fluidly connected to the metering control valve assembly; and the second hydraulic actuator fluidly connected to the metering control valve assembly via the first and second logic valves.

Preferably, the pump is a variable displacement pump. Optionally, the pump may comprise a constant pump or other pump configurations a will be appreciated by those skilled in the art.

Reference within this specification to a 'hydraulic actuator' encompass a hydraulic component having a main body or housing and at least one movable member capable of moving relative to the body or housing. The term hydraulic actuator includes a hydraulic cylinder such as a linear actuator having a cylinder body defining internal chambers separated by a piston with the piston coupled to an extendable and retractable shaft or arm. Optionally, the hydraulic actuator comprises a hydraulic motor.

Preferably, the system comprises at least four electrohydraulic valves in which a first pair of said valves is fluidly connected to the inlet and a second pair of said valves is fluidly connected to the outlet. Such an arrangement is beneficial to provide selective control of fluid flow speed and pressure to and from the actuator so as to provide a corresponding control of the movement or position of at least parts of the actuator.

Preferably, the system comprises a first and a second conduit fluidly connecting the first hydraulic actuator and the transmission valve assembly to the electrohydraulic valves; and a third and a fourth conduit fluidly connecting the second hydraulic actuator to the first and second logic valves respectively. Preferably, the first hydraulic actuator is coupled directly to the transmission valve assembly and in particular the electrohydraulic valves via the first and second conduits. Optionally, the second hydraulic actuator is coupled to the logic valves directly via the third and fourth conduits. Such an arrangement maintains to a minimum the number of components within the system for ease of maintenance and efficiency.

Preferably, the system comprises at least one or a plurality of sensors including in particular fluid flow sensors providing monitoring, output and response control of fluid pressure and flow speed (flow rate) within the system. Optionally, the sensors may be positioned at the valves, the conduits and/or the hydraulic actuators.

Optionally, the first hydraulic actuator is fluidly connected to the metering control valve assembly without fluid connection via the first and second logic valves and the second hydraulic actuator is fluidly connected to the metering control valve assembly via the first and second logic valves. Preferably, the first hydraulic actuator is coupled directly to the metering control valve assembly and the second hydraulic actuator is coupled directly to the transmission valve assembly. As such, a fluid flow speed and fluid pressure may be regulated exclusively via control of the metering control valve assembly without fluid routing via the transmission valve assembly.

Preferably, the system further comprises a first float logic valve fluidly connected to the second hydraulic actuator to allow fluid transfer between regions of the second hydraulic actuator when operated in a first mode.

Preferably, the system further comprises at least one further (i.e., third) hydraulic actuator fluidly connected to the first and second logic valves via the third and fourth conduits respectively.

Preferably, the electronically controllable valve is a solenoid control valve.

Preferably, the second and/or third hydraulic actuators are fluidly connected to the metering control valve assembly via the first and second logic valves. Preferably, the system further comprises a second float logic valve. The float logic valves are coupled directly to the respective second and third hydraulic actuators so as to minimise the fluid flow path length between the regions (i.e. internal chambers) of the actuators when operated in the first mode. Preferably, the float logic valves are pilot controlled via the transmission valve assembly and in particular the electronically controllable valve (i.e., solenoid control valve). Preferably, the float logic valves are connected to the electronically controllable valve via the same pilot fluid control circuit as the logic valves of the transmission valve assembly. Accordingly, the electronically controllable valve is configured to provide control of all logic valves within the system.

Optionally, the system further comprises a pressure reducing/relieving valve fluidly connected to an auxiliary logic valve, the pressure reducing/relieving valve fluidly connected to the pump and the auxiliary logic valve fluidly connected to at least the second hydraulic actuator. Preferably, the auxiliary logic valve is fluidly connected to the second hydraulic actuator via the third conduit. Preferably, the pressure reducing/relieving valve and the auxiliary logic valve are coupled to the drain or reservoir so as to provide further regulation of the fluid pressure at the hydraulic actuators and in particular to avoid cavitation.

Preferably, the hydraulic actuators comprises hydraulic cylinders having a first chamber and a second chamber, each respective chamber fluidly connected to the metering control valve assembly. Where the assembly comprises float logic valves, these logic valves are coupled to each of the first and second chambers such that when activated by the electronically controllable valve, at least some of the hydraulic actuators are capable of operating in a 'float' mode. Such a configuration is advantageous to control the number of 'positively activated' hydraulic actuators within the system with at least one hydraulic actuator being positively actuated by the metering control valve assembly and at least some of the hydraulic actuators being floating or idle when not supplied with fluid from the metering control valve assembly.

Preferably, the electrohydraulic valves are electrically controlled independently of one another. More preferably, the electronically controllable valve (i.e., the solenoid control valve) is electrically controlled independently of the electrohydraulic valves. Each of the electrohydraulic valves and the solenoid control valve may comprise suitable fluid flow rate and speed sensors that are in turn coupled or provided wired or wireless communication with an external control such as a computer, a network, a remote computer, processor based utility or server.

Preferably, the system comprises three hydraulic cylinders each having a first chamber and a second chamber wherein each of the first and second chambers of a first cylinder are fluidly connected directly to the electrohydraulic valves of the metering control valve assembly and each of the first and second chambers of a second and third cylinder are fluidly connected to the electrohydraulic valves of the metering control valve assembly via the logic valves of the transmission valve assembly. Such a system is particularly suitable to control a pivoting support arm of a bulk processing machine such as an undercutting mining machine.

Optionally, the electrohydraulic valves may comprise any one or a combination of proportional solenoid valves, directional control values or servo valves. Within this specification, reference to electrohydraulic valves encompasses valve types configured to control flow direction, flow volume and fluid pressure via electrical signal control of moving components (i.e., spools) within the valves. Such valves may be operated using AC or DC power.

According to a second aspect of the present invention there is provided mechanically actuating apparatus having a moveable member controlled by at least one hydraulic actuator of the hydraulic system as claimed herein.

Preferably, the mechanical actuating apparatus is an undercutting mining machine and the movable member is a support arm mounting at least one cutting head. Preferably, the hydraulic system is configured to control a pivoting of the arm at least in a direction laterally inward and outward relative to a main body or chassis of the mining machine. Optionally and additionally or alternatively, the hydraulic system may be configured to control a pivoting of the arm in a vertical plane (upward and downward direction).

BRIEF DESCRIPTION OF DRAWINGS

A specific implementation of the present invention will now be described, by way of example only, and with reference to the accompanying drawings in which:

FIG. **1** is a perspective view of a mobile undercutting mining machine suitable for creating tunnels and subterranean roadways having a pair of forward mounted pivoting cutting arms each mounting a set of roller cutter units wherein each of the cutter arms are controlled by hydraulic actuators that are in turn controlled by a hydraulic system according to one aspect of the present invention;

FIG. **2** is a schematic illustration of a hydraulic control system implemented to control movement of an actuator for fast movement and with low external force resistance in a first direction according to one aspect of the present invention;

FIG. **3** is a schematic illustration of a hydraulic control system implemented to control movement of an actuator for fast movement and with low external force resistance in a second direction according to one aspect of the present invention;

FIG. **4** is a schematic illustration of a hydraulic control system implemented to control movement of an actuator for slow movement and with high external force resistance in a first direction according to one aspect of the present invention;

FIG. **5** is a schematic illustration of a hydraulic control system implemented to control movement of an actuator for slow movement and with high external force resistance in a second direction according to one aspect of the present invention;

FIG. **6** is a schematic illustration of a hydraulic system according to a further embodiment of the present invention comprising three hydraulic actuators implemented to control movement of an actuator for slow movement and with high external force resistance in a first direction.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT OF THE INVENTION

A hydraulic system according to the present invention is capable of providing independent metering for controlled movement and static positioning of hydraulic actuators that in turn are coupled to mechanical members such as pivoting arms and the like. A specific implementation of the present hydraulic system is described with reference to movement and positional control of pivoting cutting arms of a mining undercutting machine. In particular, the present hydraulic system provides a configuration to change modes of operation of the movement of the cutting arms between for example a cutting mode in which an arm is controlled to move at slow speed and with high external load force resistance and an idling mode in which an arm is controlled to move at high speed and with low external load force resistance via the same hydraulic system.

Referring to FIG. **1**, cutting apparatus **10** is configured to cut into rock within a mining environment to create drifts, subterranean roadways and the like so as to form an underground mine network. Apparatus **10** is configured for operation in an undercutting mode in which a plurality of rotatable roller cutter units **13** may be forced into the rock to create a groove or channel and then to be pivoted vertically upward so as to overcome the reduced tensile force immediately above the channel and break the rock. Accordingly, the cutting apparatus **10** is optimised for forward advancement into the rock using less force and energy typically required for conventional compression type cutters that utilise cutting bits or picks mounted at rotatable heads.

Apparatus **10** comprises a main frame **11***a* (or chassis) that mounts a sled **11***b* capable of sliding forward and aft along a forward region of the sled **11***a*. A pair of support arms **12** are mounted at a forward region of sled **11***b* and are configured with parts to pivot independently via a generally horizontal pivot axis and a generally vertical pivot axis. A respective cutting head **15** is mounted at the distal end of each arm **12** and by rotation about the respective horizontal and vertical pivot axes is capable of being raised in a vertical plane (up and down) and to be slewed laterally in a horizontal plane (side-to-side). Each cutting head **15** mounts a plurality of cutter units **13**, with each unit **13** rotatably mounting a respective cutter ring **14** (otherwise referred to as a roller cutter). As will be appreciated, apparatus **10** further comprises additional components associated with conventional undercutting apparatus including in particular an electric motor, jacking legs, tracks etc.

The lateral slewing movement of each arm **12** is provided by selective actuation of a first pair of externally mounted hydraulic cylinders **16**, **17** and an internally mounted hydraulic cylinder **18**, with each of the three cylinders being configured to control one of the two arms via linear extension and retraction of the piston shafts as will be appreciated.

FIGS. **2** to **5** illustrate a first embodiment of the subject invention configured to provide actuation control of two hydraulic cylinders **16**, **18**. FIG. **6** illustrates a further embodiment configured for control of three hydraulic cylinders **16**, **17**, **18** illustrated by way of example to control each arm **12** of the mining machine of FIG. **1**. Referring to the embodiment of FIGS. **2** to **5** the hydraulic system comprises a variable displacement pump **21** fluidly connected to a drain or reservoir **20**. A metering control valve assembly **22** is fluidly connected via an inlet conduit **43** to pump **21**. Metering control valve assembly **22** is also fluidly connected to a drain or reservoir **20** via outlet conduit **44**. Valve assembly **22** comprises four electrohydraulic valves implemented as proportional solenoid valves **29**, **30**, **31**, **32** fluidly connected to each other, the inlet and outlet conduits **43**, **44** and a first **40** and a second **41** conduit extending from assembly **22** to provide fluid connection with hydraulic actuator **16**. As illustrated, actuator **16** comprises a cylindrical housing mounting a piston **35** coupled to a piston rod or shaft **34** capable of linear extension and retraction from the cylinder housing. First and second internal chambers **36***a*, **36***b* are partitioned by piston **35** with each chamber **36***a*, **36***b* coupled respectively to the conduits **41**, **40** and in turn the metering control valve assembly **22**. The first and second conduits **40**, **41** are positioned in fluid connection with the proportional solenoid valves **29**, **30**, **31**, **32** at a position (in fluid connection) between respective pairs of valves **29**, **32** and **30**, **31**. That is, each of the proportional solenoid valves **29** to **32** are fluidly connected together in a loop with the first and second conduits **40**, **41** fluidly coupled at regions on opposite sides of the loop.

The hydraulic system further comprises a transmission valve assembly **23** comprising a pair of logic valves **26**, **27**, a solenoid control valve **24**, a pressure reducing/relieving valve **28** and an auxiliary logic valve **25**. Solenoid control valve **24** is fluidly connected via pilot conduit **46** to logic valves **26**, **27** and is also fluidly connected to pump **21** via supply conduit **45**. Logic valve **26** is fluidly connected to the metering control valve assembly **22** via the first conduit **40** and the second logic valve **27** is fluidly connected to the metering control valve assembly **22** via the second conduit **41**. The pressure reducing/relieving valve **28** is fluidly connected to the first, second and auxiliary logic valves **25**, **26**, **27** via a reducing/relieving conduit **38**, with valve **28** also being fluidly coupled to pump **21** via supply conduit **45**.

The second hydraulic actuator **18** comprises the same configuration as the first actuator **16** and is coupled in fluid connection to the transmission valve assembly **23** via a third conduit **42** and a fourth conduit **48**. Third conduit **42** provides fluid connection between the second actuator first chamber **36***a* and the first logic valve **26** and the fourth conduit **48** provides fluid connection between the second actuator second chamber **36***b* and the second logic valve **27**. A first float logic valve **33** is provided at the second actuator **18** and is coupled to provide a fluid flow circuit between the first and second chambers **36***a*, **36***b*. Float logic valve **33** is coupled to the pilot conduit **46** so as to be pilot controlled by the solenoid control valve **24**. Float logic valve **33** is also coupled to the third and fourth conduits **42**, **48**. Each of the valves **24**, **25**, **26**, **27**, **28** and **33** are all fluidly coupled to a further reducing/relieving conduit **47** which is in turn fluidly connected to the drain or reservoir **20**. Additionally, auxiliary logic valve **25** is further fluidly connected to the third conduit **42** so as to be positioned in a fluid flow direction intermediate the pressure reducing/relieving valve **28** and the second actuator **18**.

Accordingly, first actuator **16** is fluidly connected directly to the metering control valve assembly **22** via first and second conduits **40**, **41**. Second actuator **18** is coupled indirectly to the metering control valve assembly **22** via the transmission valve assembly **23** and in particular fluid connection via the third and fourth conduit **42**, **48** and the respective first and second logic valves **26**, **27** (that are in turn coupled to the first and second conduits **40**, **41**).

According to the specific implementation, the first and second logic valves **26**, **27** are 'normally open'; the auxiliary logic valve **25** is 'normally closed' such that when solenoid control valve **24** is actuated, logic valves **26**, **27** are closed whilst auxiliary logic valve **25** is open. Accordingly, when solenoid control valve **24** is deactivated valves **26**, **27** are open and valve **25** is closed. Additionally, float logic valve **33** is 'normally closed' and like auxiliary logic valve **25**, is configured to be open by actuation of solenoid control valve **24**.

FIG. **2** illustrates control of cylinders **16** and **18** when apparatus **10** (mining machine) and in particular arm **12** is in an 'idling' mode so as to provide fast movement of arm **12** under low external load force in a first movement direction; FIG. **3** illustrates operation of the hydraulic system with the cylinders **16** and **17** operating in the same idling mode but in the reverse direction; FIG. **4** illustrates control of the cylinders **16** and **18** in a 'cutting' mode in which arm **12** is moved slowly and is maintained in a more 'stiff' configuration so as to withstand high external load force moving in a first direction and; FIG. **5** illustrates control of cylinders **16** and **18** in the same 'cutting' mode of FIG. **4** with the arm **12** moving in the opposite direction with approximately the same slow speed and similar high load balancing. FIG. **6** illustrates the embodiment of the present system controlling three linear hydraulic actuators **16**, **17** and **18** as will be described in further detail below.

As will be appreciated, the proportional solenoid valves **29** to **32** are configured to selectively regulate fluid flow speed and pressure via independent electronic controls. The fluid flow and valve control configuration is described with reference to FIG. **2** and it will be appreciated that corresponding fluid flow directions and valve control configurations are applied equally to the different modes and operation of the linear actuators **16**, **18** according to the desired direction of movement of the shafts **34** according to FIGS. **3** to **5**. As illustrated in FIG. **2**, fluid is supplied to the metering control valve assembly **22** via pump **21** and inlet conduit **43**. Fluid is then supplied at the desired rate and pressure to cylinder second chamber **36***b* via first conduit **40**. Fluid from cylinder first chamber **36***a* is directed to the drain or reservoir **20** via the second conduit **41**, the metering control valve assembly **22** and the outlet conduit **44**. In this configuration, cylinder **16** is 'active' whilst cylinder **18** is maintained in a 'floating' mode without fluid supply from the metering control valve assembly **22**. In this mode of operation, fluid flows from first chamber **36***a* of second cylinder **18** to the second chamber **36***b* via float logic valve **33**. Excess fluid (due to the difference in chamber size) from the first chamber **36***a* is transferred to the reducing/relieving conduit **47** via third conduit **42**, auxiliary logic valve **25** and pressure reducing/relieving valve **28**. This mode of operation according to FIG. **2** is provided by activating solenoid **24** to close valves **26**, **27** and open valve **25**. In the reverse flow direction illustrated in FIG. **3**, the pressure reducing/relieving valve **28** is controlled to provide the reverse fluid flow direction through auxiliary logic valve **25** so as to provide the opposite fluid flow direction between the first and second chambers **36***a*, **36***b* of second cylinder **18**. Naturally, the reverse fluid flow direction through first and second conduits **40**, **41** is provided by the selective electronic control of the four proportional solenoid valves **29** to **32**.

Referring to FIGS. **4** and **5**, where it is required to actuate cylinders **16** and **18** according to the 'cutting' mode (i.e. with slow speed and high stiffness/high external load force resistance) solenoid control valve **24** is deactivated so as to allow fluid flow from metering control valve assembly **22** to the second cylinder **18** via logic valve **26**. In this configuration, the metering control valve assembly **22** is provided in fluid connection to both cylinders **16**, **18** and accordingly the fluid flow speed and pressure is divided approximately equally to achieve a higher force resistance and a proportionally lower actuation speed relative to the 'fast' mode of operation of FIGS. **2** and **3**. In such a configuration the pressure reducing/relieving valve **28** and the auxiliary logic valve **25** are isolated from the fluid flow at the first, second, third and fourth conduits **40**, **41**, **42** and **48**.

The components, construction and functionality of the embodiment of FIG. **6** is the same as the embodiment of FIGS. **2** to **5** save for the additional actuator **17** and a corresponding additional float logic valve **37** (associated with the actuator **17**). As illustrated, the second and third actuators **18**, **17** are fluidly connected via the third and fourth conduits **42**, **48** and in particular the first chamber **36***a* of the second actuator **18** is coupled to the second chamber **36***b* of the third actuator **17** via the third conduit **42** and the second chamber **36***b* of the second actuator **18** is coupled to the first chamber **36***a* of the third actuator via the fourth conduit **48**. Accordingly, excess fluid from the first respective chamber **36***a* may be transferred to the respective to the second chamber **36***b* of the alternate actuator **18**, **17** when the second and third actuators **18**, **17** are operated in 'float' or 'idling' mode and not driven directly by the metering control valve assembly **22**. As with the embodiment of FIGS. **2** to **5**, regulation of the fluid supply pressure and flow rate to the second and third actuators **18**, **17** is controlled via the metering control valve assembly **22** when solenoid control valve **24** is deactivated and the logic valves **26** and **27** are opened as default. As will be appreciated, the third actuator **17** is configured for the same corresponding directional movement of the first actuator **16** such that first and third actuators **16**, **17** are motion paired and the second actuator **18** is operable in the corresponding reverse stroke direction. As with the embodiment of FIGS. **2** to **5**, both the second and third actuators **18**, **17** and in particular the respective first and second chambers **36***a*, **36***b* are fluidly coupled to the drain or reservoir **20** via the reducing/relieving conduit **47**, the third conduit **42**, the auxiliary logic valve **25** and the pressure reducing/relieving valve **28** so as to provide regulation of the fluid flow given the respective differences in the volumes of the first and second chambers **36***a*, **36***b*. Additionally, and as with the embodiment of FIGS. **2** to **5**, the auxiliary logic valve **25** and the associated pressure reducing/relieving valve **28** are capable of supplying a constant pressure to the second and third actuators **18**, **17** and of avoiding cavitation via fluid connection to the drain or reservoir **20** via reducing/relieving conduit **47**.

The present hydraulic system provides a mechanism and a method of controlling the speed of pivoting movement of the arms **12** in the lateral inward and outward direction in addition to providing control of the 'stiffness' of the movement and hence a relative resistance to the external load applied to the arms primarily resultant from contact with the rock strata when in cutting mode. For example, and in a fast mode of operation, only the first actuator **16** is positively displaced by metering control valve assembly **22** corresponding to a non-cutting operation as the arm **12** is returned to an in-board position. In a cutting mode, all three actuators **16**, **17**, **18** are positively displaced so as to distribute the applied fluid pressure from the metering control valve assembly **22** and to provide greater resistance to the external load as the cutting units **13** are forced against the rock strata during cutting. A maximum load would be encountered for example when arm **12** is extended fully (orientated approximately 90° to the orientation of FIG. **1**) via pivoting of the arm **12** about the generally horizontal axis). In such a position, proportional solenoid valves **29** to **32** would be controlled so as to deliver maximum pressure to the actuators **16**, **17**, **18** with low fluid flow speed.

By utilising proportional solenoid valves, at least one solenoid control valve and logic valves, the present hydraulic system provides a versatile mechanism and method for quantitative adjustment of the speed of movement and force of displacement of the actuators **16**, **17**, **18** according to predefined operating conditions.

The invention claimed is:

1. A hydraulic system to control at least two hydraulic actuators, the system comprising:

a pump;

a first and a second hydraulic actuator;

a metering control valve assembly having a plurality of electrohydraulic valves, an inlet fluidly connected to the pump and an outlet fluidly connected to a drain or reservoir, the metering control valve assembly fluidly connected to the first hydraulic actuator; and

a transmission valve assembly having an electronically controllable valve fluidly connected to provide pilot control of a first and a second logic valve, the first and second logic valves being fluidly connected to the metering control valve assembly, wherein the second hydraulic actuator is fluidly connected to the metering control valve assembly via the first and second logic valves.

2. The system as claimed in claim **1**, comprising at least four electrohydraulic valves in which a first pair of said valves is fluidly connected to the inlet and a second pair of said valves is fluidly connected to the outlet.

3. The system as claimed in claim **1**, further comprising a first and a second conduit fluidly connecting the first hydraulic actuator and the transmission valve assembly to the electrohydraulic valves; and a third and a fourth conduit fluidly connecting the second hydraulic actuator to the first and second logic valves respectively.

4. The system as claimed in claim **3**, wherein the first hydraulic actuator is fluidly connected to the metering control valve assembly without fluid connection via the first and second logic valves and the second hydraulic actuator is fluidly connected to the metering control valve assembly via the first and second logic valves.

5. The system as claimed in claim **1**, further comprising a first float logic valve fluidly connected to the second hydraulic actuator to allow fluid transfer between regions of the second hydraulic actuator when operated in a first mode.

6. The system as claimed in claim **1**, further comprising a third hydraulic actuator fluidly connected to the first and second logic valves via the third and fourth conduits respectively.

7. The system as claimed in claim **6**, wherein the second and/or third hydraulic actuators are fluidly connected to the metering control valve assembly via the first and second logic valves.

8. The system as claimed in claim **5**, further comprising a third hydraulic actuator fluidly connected to the first and second logic valves and a second float logic valve fluidly connected to the third hydraulic actuator to allow fluid transfer between regions of the third hydraulic actuator when operated in the first mode.

9. The system as claimed in claim **5**, further comprising a pressure reducing/relieving valve fluidly connected to an auxiliary logic valve, the pressure reducing/relieving valve being fluidly connected to the pump and the auxiliary logic valve fluidly connected to at least the second hydraulic actuator.

10. The system as claimed in claim **9**, wherein the auxiliary logic valve is fluidly connected to the second hydraulic actuator via the third conduit.

11. The system as claimed in claim **1**, wherein the hydraulic actuators include hydraulic cylinders having a first chamber and a second chamber, each respective chamber fluidly connected to the metering control valve assembly.

12. The system as claimed in claim **1**, wherein each of the electrohydraulic valves are electrically controlled independently of one another.

13. The system as claimed in claim **1**, wherein the electronically controllable valve is a solenoid control valve electrically controlled independently of the electrohydraulic valves.

14. The system as claimed in claim **1**, comprising three hydraulic cylinders each having a first chamber and a second chamber, wherein each of the first and second chambers of a first cylinder is fluidly connected directly to the electrohydraulic valves of the metering control valve assembly and each of the first and second chambers of a second and third cylinder are fluidly connected to the electrohydraulic valves of the metering control valve assembly via the logic valves of the transmission valve assembly.

15. A mechanical actuating apparatus having a moveable member controlled by at least one hydraulic actuator of the hydraulic system as claimed in claim **1**.

16. The apparatus as claimed in claim **15**, wherein the mechanical actuating apparatus is an undercutting mining machine and the movable member is a support arm mounting at least one cutting head.

17. The apparatus as claimed in claim **16**, wherein the hydraulic system is configured to control a pivoting of the support arm in a direction laterally inward and outward relative to a main body or chassis of the mining machine.

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